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Cotton genetic resources in the western states of Mexico: *in situ* conservation status and germplasm collection for *ex situ* preservation

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Abstract

The *Gossypium hirsutum* gene pool from Mexico is one of the primary sources for improvement of most of the Acala and Upland cotton growing in the world today. Mexico is also the center of diversity of the *Gossypium* genus with 11 of the 13 known diploid *Gossypium* species of the Western Hemisphere endemic to its boundaries. In 2002 and 2003, the current status of these important genetic resources was surveyed, and germplasm was collected in the western states of Mexico. Information was collected to verify current status and circumscription of the endemic *Gossypium* species. Sixty years after the first in-depth studies of *Gossypium* in Mexico, increasing human population, modernization and urbanization have severely reduced the survival of *G. hirsutum* landraces. Representatives of cotton landraces evidently survive only as curiosities in garden plots or dooryards, or as occasional feral plants. Populations of seven known species, *G. aridum*, *G. barbadense*, *G. gossypioides*, *G. hirsutum*, *G. laxum*, *G. lobatum*, and *G. schwendimanii*, and one undescribed wild diploid *Gossypium* taxon were located during the survey. *In situ* conservation of some of these species is threatened. Samples of the collected germplasm were deposited in the Cotton Collection of the US National Plant Germplasm System where they will be available to scientists worldwide for research, breeding, and education. Additionally, a *Gossypium* species nursery is being established by the Mexican government for the preservation, and as a working legacy, of this resource. Knowledge of the diversity and, consequently, utilization of the genetic resources in these species cannot be fully realized *in situ* under current conditions.

Introduction

Mexico is the center of origin and of diversity of *Gossypium hirsutum* L. the most widely cultivated cotton in the world, which is known by various common names including, among others, Acala or Upland cotton, short staple cotton, Mocó cotton, and Cambodia cotton (Johnson 1926). Although expeditions to collect cotton germplasm in Mexico during the last century are not well documented, and it is difficult to find published information, we were able to obtain unpublished reports on some of the expeditions. In the first half of the 20th century, cotton germplasm was collected in

southern Mexico and Central America by T.R. Richmond and C.W. Manning in 1946, S.G. Stephens in 1947, and J.O. Ware and C.W. Manning in 1948 (USDA, ARS Series H-2 Oct, 1974). Based largely on these collections, the first organized assessment of the cottons of Mexico was undertaken, and a series was of eight "landraces" was established that roughly corresponded to areas of production or geographic occurrence (Palomo-Gil 1996). Since the initial delineations, cotton scientists involved in germplasm collection, maintenance and evaluation have not assigned new accessions into these landrace categories, except for the most obvious types (i.e., palmeri, marie galante, and yucatanense) (Percival 1987).

Another series of collection expeditions were conducted in the last 30 years of the 20th century. In 1977–1978, N. Lemeshev (USSR) and Q. Obispo (Mexico) carried out several expeditions covering 16 Mexican states, including Veracruz, Tabasco, Campeche, Yucatán, Quintana Roo, Chiapas, Oaxaca, Guerrero, Michoacán, Jalisco, Colima, Nayarit, Sinaloa and the peninsula of Baja California. In addition to *G. hirsutum*, seeds of seven *Gossypium* species (*G. armourianum* Kearney, *G. harknessii* Brandegee, *G. trilobum* (DC) Skovsted, *G. aridum* (Rose et Standley) Skovsted, *G. lobatum* Gentry, *G. laxum* Phillips, and *G. gossypioides* (Ulbrich) Standley) were obtained. Between 1989 and 1993, F. Talipov, C. Cataláio, F. Salgado and M. Bahena carried out several expeditions for the Universidad Autónoma de Guerrero and the Academy of Science of Russia in the states of Veracruz, Tabasco, Campeche, Yucatán, Chiapas, Guerrero, Oaxaca, Michoacán, Morelos, Colima, Sinaloa, Sonora and Baja California Sur. The accessions collected during these expeditions most likely are reported to be in the germplasm collection of the Vavilov Institute in St. Petersburg, but passport data are unavailable and their long-term survival and availability to others are in question. A *Gossypium* nursery established by Dr. Lemeshev in Iguala, Guerrero was abandoned upon his return to Russia (Q. Obispo, personal communication). In 1984, Zhong FrangChen, Shao AnHo (PRC), C. Arroyo, A. Palomo and A. Hernandez (Mexico-INIFAP) were involved in a search for wild cotton species, but the status of the germplasm obtained on these expeditions is unknown. In 1984, A.E. Percival, J.M. Stewart (USDA), A. Hernandez and F. de Leon (INIFAP) collected throughout the states of the Yucatán Peninsula and in parts of the states of Tamulipas, Veracruz, Tabasco, Oaxaca and Chiapas (Percival 1987). In 1990, A.E. Percival (USDA-ARS), J.M. Stewart (University of Arkansas), E.A. Garcia, and L. Peréz (SAGAR-INIFAP Mexico) explored the state of Baja California Sur and parts of Sonora and Sinaloa. The germplasm accessions from the latter two expeditions are available in the USDA Cotton Germplasm Collection (USDA-ARS, College Station, TX). Although Mexico's natural heritage of cotton genetic resources equals that of maize, until very recently no national resources had been dedicated to the preservation of this natural treasure. As a consequence, no cotton germplasm has been preserved *ex situ* in the country.

During the 60 years that have passed since the first collections were made, the *in situ* survival of Mexican cotton germplasm has been threatened with increasing human population, modernization of agriculture and urbanization. The length of time during which these factors have been affecting landrace survival indicated a dire need for an updated assessment of the *in situ* status of the landraces of *G. hirsutum*. If *in situ* diversity of the Mexican cottons is severely eroded, the accessions in the USDA Cotton Germplasm Collection assume a highly significant role in preserving the diversity previously residing in Mexico's dooryard cottons.

In addition to being the center of origin of *G. hirsutum*, 11 of the 13 known wild diploid *Gossypium* species in the Western Hemisphere are endemic to Mexico. Some of the diploid species are adapted to the desert environments of Baja California (*G. armourianum*, *G. harknessii*, and *G. davidsonii* Kellogg) and NW mainland Mexico (*G. turneri* Fryx. and *G. thurberi* Todaro).

The remaining six of the known wild diploid species (*G. aridum*, *G. lobatum*, *G. laxum*, *G. schwendimanii* Fryx. et Koch, *G. gossypioides* and *G. trilobum* (DC.) Skovsted) are located in the Pacific coast states of Mexico and, with the exception of the last species, are arborescent in growth habit. Herbarium records (MEXU) of *Gossypium trilobum* indicate that this species occurs at elevations between 1000 and 1500 m where environmental conditions are more mesic than at lower elevations. The other five species are found in deciduous woodlands with distinct seasonal wet

and dry periods and are deciduous during the dry season. Taxonomically, the five species are in the same section (*Erioxylum*) and, with the exception of *G. gossypioides* (subsection *Selera*, are in the same subsection (*Erioxylum*) (Fryxell 1992). These species generally have not been extensively collected, and the ranges of their distributions are unknown. *Gossypium aridum*, as currently circumscribed (Fryxell 1992), has the largest known range, extending from Sinaloa to Oaxaca. Herbarium (MEXU) specimens of the other species suggest that they have highly restricted distributions in Guerrero and Michoacán. These species are probably the least known and utilized of the *Gossypium* species of the Western Hemisphere because of their arborescent growth habit and unique flowering and fruiting habit (following defoliation in the dry season).

To assess the current status of *Gossypium* genetic resources in Mexico, a series of USA/Mexico collaborative expeditions were conducted in those areas and states where cultivated and wild *Gossypium* were known to occur, but that had not been surveyed for several decades. This paper summaries the results and observations from four expeditions conducted in 2002 and 2003 in the western states of Mexico.

Expeditions and survey strategies

The first expedition was conducted 23 February–21 March 2002 in parts of the states of México, Morelos, Puebla, Chiapas, Oaxaca, Guerrero, and Michoacán (Figures 1 and 2a–d). During 17–21 November 2002 two of the authors, Dr. Ulloa (MU) and Dr. Stewart (JMS) revisited a site near Oxtutla, Guerrero to obtain herbarium specimens including flowers and vegetative growth of an unusual *Gossypium* taxon for which only mature capsules were available the previous March. The third expedition occurred during February, 2003 in the states of México, Michoacán, Colima, Jalisco, and Nayarit. Near the scheduled end of the third expedition, the participants learned of a possible landrace being cultivated by indigenous peoples in the NE corner of Nayarit, an area in which herbarium (MEXU) records indicated that a diploid *Gossypium* also occurred. Because of the time required to reach the remote area, and the possibility that the diploid species would not have mature seed at that time (based on *G. aridum* populations near Tepic, Nayarit), the expedition team did not visit the area at that time. However, MU and JMS returned to Nayarit 23–27 April 2003 and visited the NE area as well as other parts of Nayarit. The routes for these two expeditions are mapped in Figures 1 and 3a–d.

The expeditions in February of 2002 and 2003 began with visits to the Mexican National Herbarium (MEXU) at the Universidad National Autónoma de México (UNAM) in Mexico City. A record was made of each location where a *Gossypium* herbarium specimen had been collected in the target states. Based on these locations, a tentative route for the expedition was established. Modifications of the itinerary were made in the field as new information was obtained.

The primary means of travel was by automobile, so with a few exceptions, areas inaccessible by road were not visited. In each area, an effort was made to engage an individual familiar with the area and indigenous language as a guide to facilitate interactions with local people and to provide advice on traveling conditions. Particular attention was given to dooryard plants of *G. hirsutum* and *G. barbadense*, that were most likely encountered in settlements. Local information was used extensively to identify dwellings in pueblos where garden plants might be maintained. The diploid species are usually associated with dry deciduous woodlands and are most frequently found in canyons, along drainage courses, or on disturbed road banks and hillsides. Generally, the diploid species were encountered through close observation in likely ecological niches by expedition members; however, in a few instances, local knowledge of the plants led to areas that the team would otherwise have missed.

In most cases, *Gossypium* species are present as outcrossing populations, so seed collections from several plants of the population were bulked. In the case of garden plants of cotton, seeds of several plants with an apparent common parental origin were collected in bulk. On the other hand, if morphological differences were present among plants in a garden, seeds were collected by plant type. Each accession was assigned a field collection number, and passport and habitat data were recorded on site. The passport information included latitude and longitude determined by GPS and altitude for the site. Herbarium voucher specimens

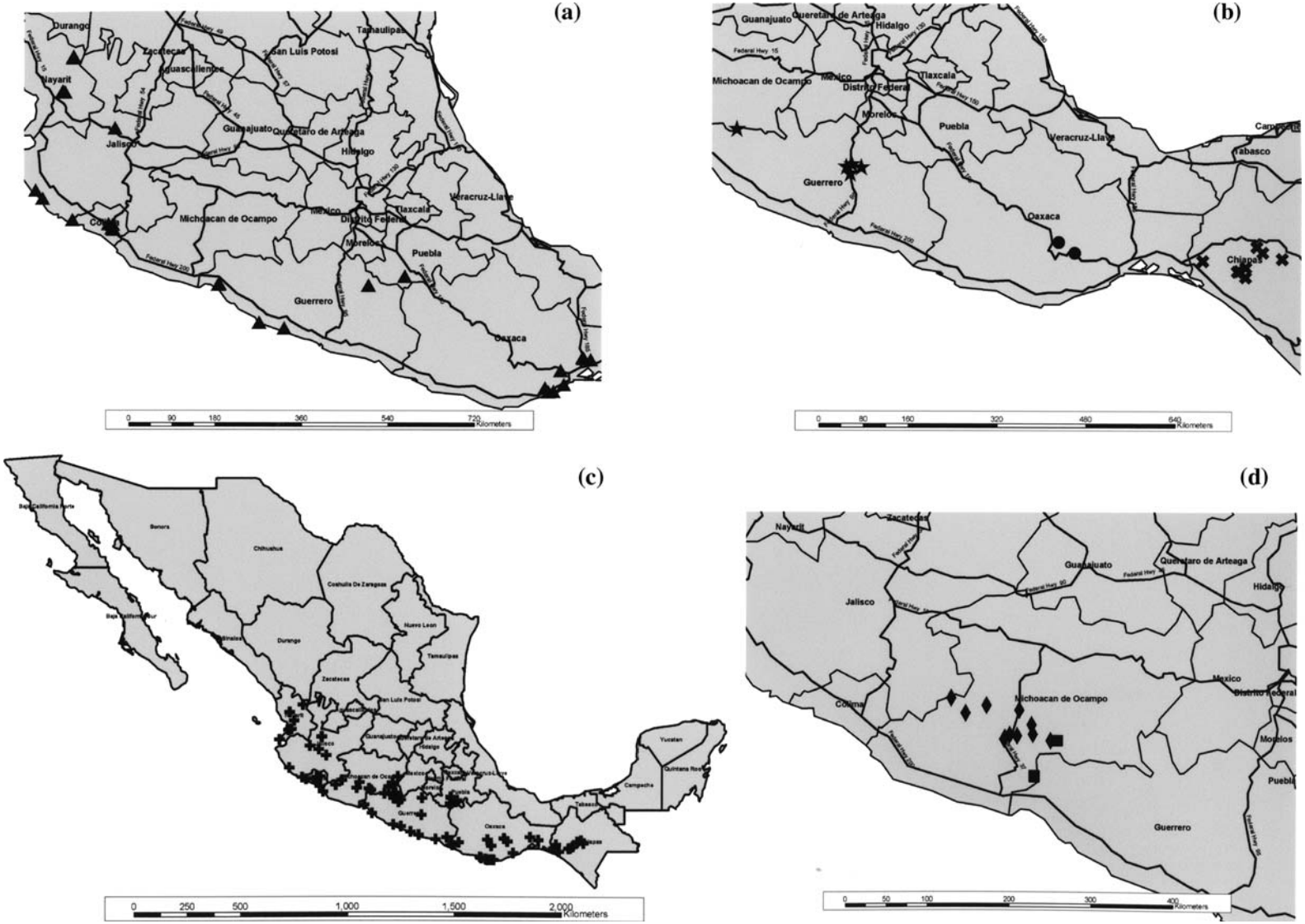
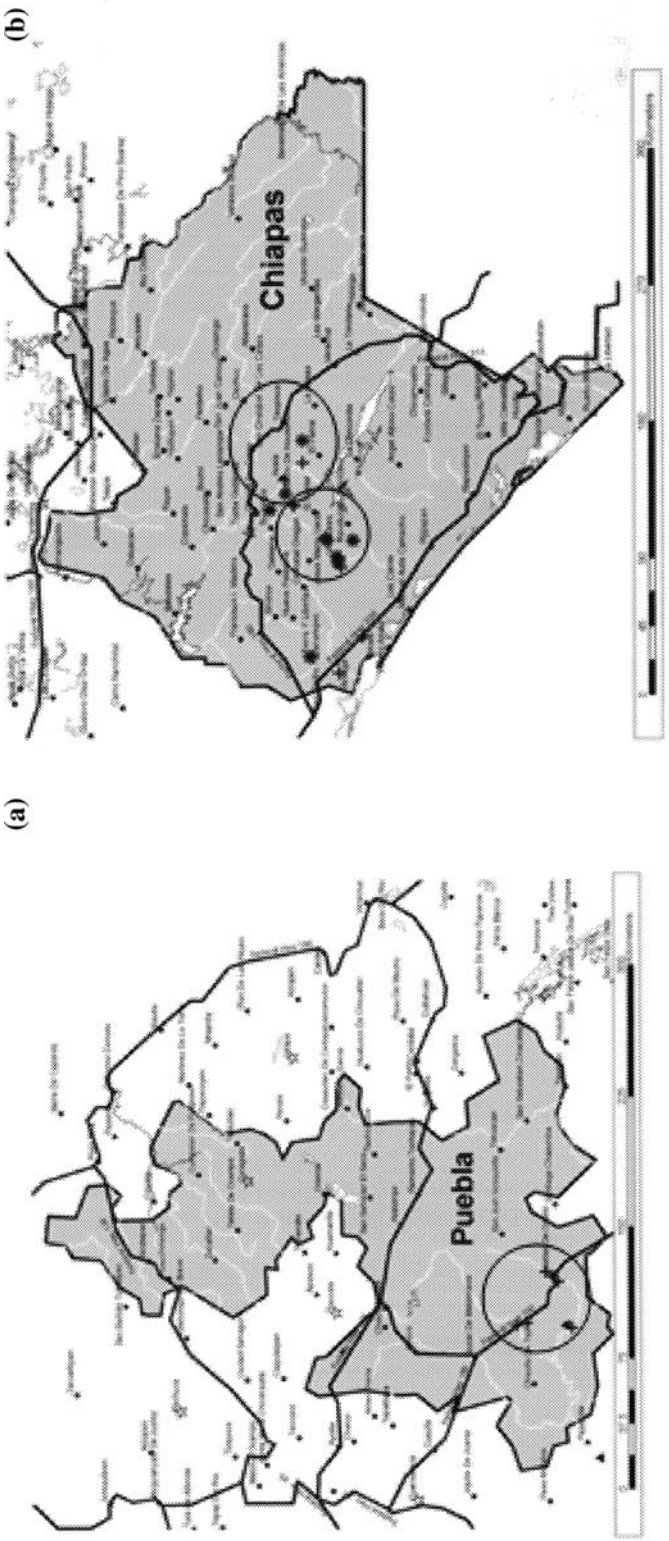


Figure 1. The country of Mexico, states, and location sites where *Gossypium* species were collected from the four cotton expeditions. *Gossypium* species identified by different symbols: (1a) *G. aridum* (▲), (1b) *G. barbadense* (×), *G. gossypioides* (●) and *G. laxum* (*), (1c) *G. hirsutum* (+) and (1d) *G. lobatum* (◇), and *G. schwendimanii* (■).


(b)
Chiapas
(a)
Puebla

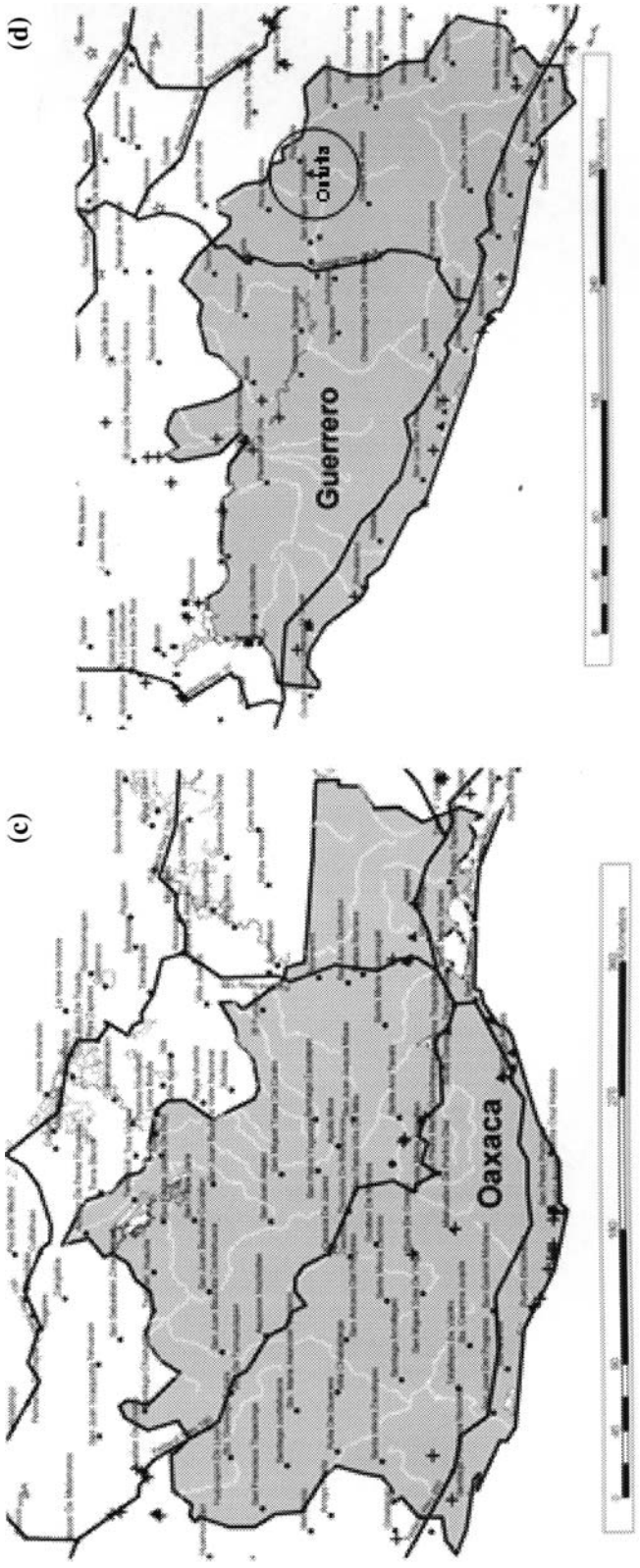


Figure 2. Location sites where *Gossypium* species were collected from two cotton expeditions and different states of the country of Mexico, 2a state of Puebla, 2b state of Chiapas, 2c state of Oaxaca, and 2d state of Guerrero. *Gossypium* species identified by different symbols: *G. aridum* (▲), *G. barbadense* (×), *G. gossypioides* (●), *G. hirsutum* (+), *G. laxum* (*), *G. lobatum* (◇), and *G. schwendimanii* (■). Circles around sites on some states emphasize specific collections.

cross-referenced to the field seed-collection number were obtained to represent each of the accessions collected. For the diploid *Gossypium* species accessions, a duplicate voucher was deposited in MEXU. The remaining vouchers are currently held by JMS and will be deposited in New York NY (New York Botanical Garden 2003).

In all instances in which seed samples of the *Gossypium* species were collected, they were shared equally between the USA and Mexican participants. The USA samples have been deposited in the USDA Cotton Germplasm Collection. When the accessions have been successfully regenerated, they will be available through the US National Germplasm System for research, breeding, and education. A Mexican Permanent Cotton Nursery was established in late 2002 by INIFAP in Iguala, Guerrero, and the diploid species accessions collected in 2002 have been established in the nursery. In addition, diploid *Gossypium* species endemic to other parts of Mexico have been placed there. The diploid *Gossypium* species collected in 2003 are currently being established in this nursery.

Table 1. Number of seed accessions collected of each *Gossypium* species by year.

Species	2002	2003	Total
G. hirsutum	53	38	91
G. barbadense	9	0	9
G. gossypioides	2	0	2
G. aridum	15	13	28
G. laxum	5	0	5
G. lobatum	1	11	12
G. schwendimanii	2	1	3
G. sp. nov.	1	0	1
G. trilobum	0	0	0

Seeds collected for *ex situ preservation*

In 2002, 86 seed accessions comprising seven known *Gossypium* species were collected. In addition, seeds of one taxon that evidently represents an undescribed taxon were collected. In 2003, an additional 63 seed accessions comprising four species were added. A summary of the number of accessions by species is presented in Table 1, and the number of species by state is listed in Table 2.

Observations on the *in situ* status of *Gossypium* species

Gossypium hirsutum

The geographic center of genetic diversity of *G. hirsutum* is in southern Mexico and neighboring Guatemala (Brubaker and Wendel 1994). The landraces of *G. hirsutum* are the primary germplasm pool from which genes for future cotton improvement will come (Stewart 1995). With one exception, we found that the landraces are no longer cultivated for cotton production in Mexico, and except in the Yucatán Peninsula area (Percival and Stewart, personal communication), populations of *G. hirsutum* outside of garden cultivation could not be located. In none of the 10 states visited during these expeditions could one say that cotton was plentiful. One to a few plants were encountered only occasionally and often only after several inquiries were made of residents in each pueblo. Many of these settlements had no cotton plants.

The diversity that remains *in situ* is limited to feral plants that occur opportunistically in waste

Table 2. Distribution of *Gossypium* collections by species among the western states of Mexico.

States	*Gossypium* species								Total
	aridum	*barbadense*	*gossypioides*	*hirsutum*	*laxum*	*lobatum*	*schwendimanii*	sp. nov.	
Colima	5	0	0	7	0	0	0	0	12
Puebla	2	0	0	7	0	0	0	0	9
Oaxaca	8	0	2	22	0	0	0	0	32
Chiapas	0	9	0	13	0	0	0	0	22
Guerrero	3	0	0	12	5	0	0	1	21
Michoacán	2	0	0	15	0	12	3	0	32
Jalisco	3	0	0	11	0	0	0	0	14
Nayarit	5	0	0	4	0	0	0	0	9
Total	28	9	2	91	5	12	3	1	

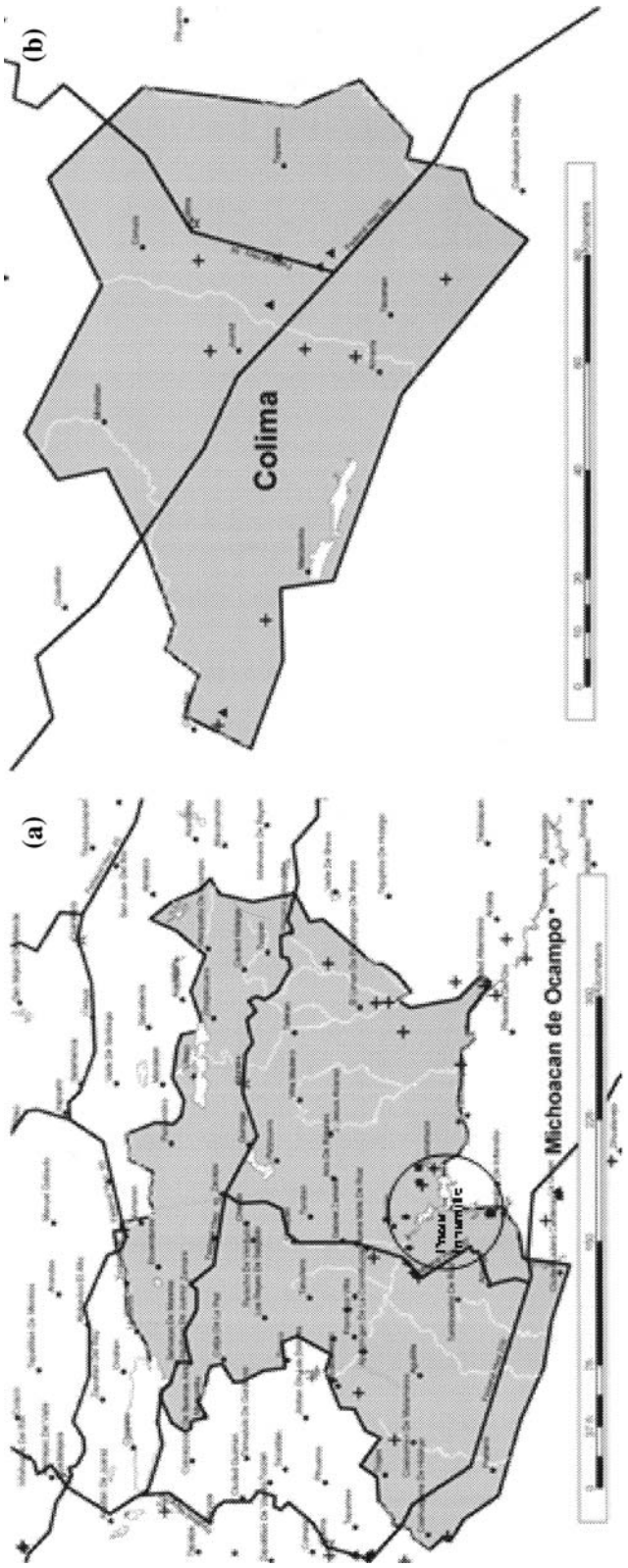

(b)
Colima
(a)
Michoacan de Ocampo

Figure 3. Location sites where *Gossypium* species were collected from two cotton expeditions and different states of the country of Mexico, 3a state of Michoacán, 3b state of Colima, 3c state of Jalico, and 3d state of Nayarit. *Gossypium* species identified by different symbols: *G. aridum* (▲), *G. barbadense* (×), *G. gossypioides* (●), *G. hirsutum* (+), *G. laxum* (*), *G. lobatum* (◇), and *G. schwendimanii* (■). Circles around sites on some states emphasize specific collections.

areas and as occasional home garden plants maintained as a novelty by rural peoples or village residents. According to information obtained from local sources, in areas where commercial cotton production was attempted (around 1980), feral or dooryard plants were often destroyed in the misguided belief that they were served as a reservoir for insects. Apparently all attempts at commercial cotton production in southern Mexico have been abandoned. No commercial fields of cotton were encountered during these expeditions.

Long-term survival of populations outside of gardens or disturbed waste areas is questionable. Human activities, such as horticulture, road construction, land clearing, trash heaps, etc., are generally required for creation of the disturbed areas where cotton plants can become established and survive. Clearly some of the landrace types are better adapted to survival in this type of environment than are others. Particularly in western Oaxaca and Guerrero, landrace palmeri frequently escapes from garden culture and survives in disturbed waste areas such as roadbanks and fence rows. Very little insect damage was observed on these plants, but this could be related to the fact that plants or populations generally are several kilometers apart; hence, populations of cotton-adapted pests are not promoted.

In the geological feature called the Central Depression of Chiapas all the cotton plants were normal-leaf type and were either in garden cultivation or were escapes closely associated with such plants. The pueblo of Acala Chiapas is famous as the namesake and origin of the germplasm that contributed to the high quality cottons of California and New Mexico. The original germplasm used to develop these cottons was collected by G.N. Collins and C.B. Doyle near Acala in 1906 (Niles and Feaster 1984). Extensive search of the countryside around Acala during the current surveys confirmed that very little cotton remains in that area, even as garden plants. Only five samples of *G. hirsutum* were collected in pueblos surrounding Acala. These accessions had low productivity and inferior fiber quality typical of genotypes not under production but which have survived under conditions of neglect in the area. Thus, it has the traits that maximize perennial survival in a seasonally dry climate rather than those traits that would maximize annual productivity under cultivation during the rainy season.

Acala is located on the northeast side of the Central Depression, whereas Villa Flores is on the southwest side of this geological formation. Our explorations in a semicircular area to the south of Villa Flores also yielded five accessions of *G. hirsutum*. However, since this was a considerably smaller area than that surveyed around Acala, the impression was that more residual cotton plants were present in the Villa Flores area. Intuitively, the genetic diversity of the cotton in this area also seemed to be greater than in the Acala area, but this needs to be confirmed during evaluation of the accessions. One accession that was particularly notable for its productivity and fiber quality may be a remnant from an imported cultivar that was grown in the area in the 1970s, but this is uncertain.

Since the Central Depression of Chiapas experienced a period of cotton production followed by abandonment during the middle of the 20th century, survival of the genetic diversity that was in the original landrace(s) of the area cannot be confirmed. One must assume that the vast majority of it is no longer extant, since most of the local cotton plants were destroyed during the period of imported cotton cultivation so they would not serve as reservoirs for insect pests (communicated by local authorities of the community). On the other hand, the genetic lines that have survived do so because they possess characteristics that are adapted to the prevailing environment. The materials collected in all of the southern states should not be viewed as an effort to capture the past, but as representing potentially useful genetics because of their present-day survival, however tenuous.

Given the infrequent occurrence of commensal or ruderal *G. hirsutum* in southern Mexico, it is interesting that regional phenotypic differences were still very evident among the garden plants and escapes that were encountered. As noted above, all *G. hirsutum* observed in Chiapas possessed the growth habit and "normal" leaf structure typical of landraces punctatum and latifolium. In western Oaxaca, Guerrero, and eastern Michoacán almost all plants of *G. hirsutum* were of the palmeri landrace, characterized by numerous small flowers and bolls, lanceolate leaf lobes (okra leaf), multi-branched erect growth habit, and ability to withstand drought by defoliation during the dry period. These characteristics

have helped the landrace to survive the dry seasons that are a feature of the area where it is the predominant type.

As one moves into western Michoacán, Colima, Jalisco and Nayarit, the prevailing genotypes of *G. hirsutum* are again normal-leaf types with a more spreading growth habit. Only one population of the palmeri landrace was seen in the latter three states. A considerable range of morphological diversity was noted among the *G. hirsutum* accessions collected in the west central Pacific states, and these probably are representative of the less well-known landraces.

Occasional incidences of long-term *in situ* preservation are noteworthy. We visited a small farm in south central Oaxaca where cotton was growing in the garden and as a few escapes on the roadside. The elderly woman residing there related that her grandfather always had cotton when she was a little girl. She had maintained it by saving seed and replanting every few years to ensure that some cotton was always growing. Based on her story, the population was estimated to be conserved there for at least 70 years.

Through local contacts, we learned of a landrace of brown-linted *G. hirsutum* in western Oaxaca that was being cultivated by members of a cooperative as part of a cottage industry. The President of the cooperative indicated that the lint was handspun and woven into handcraft items for export to Mexico City and elsewhere for the indigenous arts and crafts trade. Although the expedition team arrived in the area after dark and was unable to see the production areas, seeds of the landrace were provided by the President. The existence of the brown-fibered population in the area pre-dated the memory of the President (estimated at approximately 40 years). This was the only case where the survey encountered a landrace of cotton being grown for commercial production.

In Tepic, Nayarit, we learned via an itinerate medical doctor of the possibility of a landrace of cotton being grown by the Huichol and Cora Indians in a remote area of NE Nayarit centered around the town of Jesus Maria. Apparently this cotton was grown for use in religious ceremonies. Our guide from the region introduced us to the wife of the second (Vice) Governor Indio of the Cora Tribe who provided us with a small bag of phenotypically diverse seed recently harvested from her garden away from the pueblo. We also visited another dwelling in Jesus Maria where five plants representing two distinct genotypes were growing in the garden. Although our primary contact was with the Cora Tribe rather than the Huichol, we suspect that the use of cotton does not vary significantly between the tribes. These observations, as well as the absence of any production fields in the area, indicated that the *G. hirsutum* used in ceremonies was maintained in heterogenous mixtures in garden plots.

In summary, these expeditions have provided samples of the remaining genetic diversity of *G. hirsutum* in southern Mexico. Extensive loss of local landraces has occurred in the southern and western Mexican states, and garden plants are the remaining vestige of the *in situ* genetic diversity of the landraces. The earlier collections conserved in the USDA Cotton Germplasm Collection and in the Vavilov Institute Collection probably represent a greater range of cotton genetic diversity than now exists *in situ*.

Gossypium barbadense

This species is not generally thought to be significant in Mexico. It was encountered only in Chiapas as a garden plant, but then nearly as frequently as *G. hirsutum*. No feral plants were seen. With only a few exceptions, the accessions encountered belonged to the subspecies *brasiliense*, commonly known as "kidney-cotton", which is characterized in part by fusion of the seeds of a locule. This material was probably introduced via early trade and does not represent indigenous diversity.

Gossypium aridum

This species, as currently circumscribed, is the most widely distributed wild *Gossypium* in Mexico, occurring from Sinaloa to Oaxaca (Fryxell 1979). As expected from its wide range, this *Gossypium* species occupies a number of niches with what is best described as various ecotypes. Comparisons among herbarium specimens in MEXU and on-site observations indicate extensive differences in leaf size, vestiture of the leaves, morphology in the lysigenous glands on the capsules, and period of flowering. In Oaxaca, it occurs in the deciduous forests along the lower coastal foothills from

about the center of the state eastward to the Isthmus of Tehuantepec. Morphologically, the leaves of the ecotype from this area are the largest of the species, with a relatively dense but fine indumentum. A population of *G. aridum* was also encountered in SW Puebla that resembled the coastal ecotypes from the more northerly states. This population was located on a watershed that runs into the Rio Balsas, a major river and canyon system that traverses Guerrero and Michoacán and that figures significantly in the distribution of *Gossypium* in Mexico, as later discussions will show.

Several populations of *G. aridum* that appear to be very similar in morphology are distributed along the coastal foothills (< 60 m elevation) of Jalisco, Colima, Guerrero, and possibly Michoacán. Generally, these populations have almost no leaf trichomes, and their leaves and mature capsules are somewhat smaller than those of *G. aridum* from Oaxaca. In the western part of Guerrero in the area of Presa Infiernillo and perhaps as far south as the coast (e.g., La Union area) near the known range of *G. schwendimanii*, *G. aridum* plants have some characteristics resembling this latter species. This may be an indication of natural gene flow between the two species.

In addition to the coastal populations, we located populations of *G. aridum* at higher elevations in Colima and Jalisco. In Colima, we found plants along the slopes and canyons of the coastal range between the city of Colima and the coast at elevations of 300–400 m. The leaves and capsules of this ecotype are the smallest of the species. On the other hand, the highland ecotype of Jalisco occurs at elevations of 800–1000 m. and is similar to the highland ecotype near Tepic, Nayarit. These populations are associated with the watershed and canyons formed by the Rio Grande de Santiago. Morphologically, plants of the highland populations are unique in having very hirsute calyces with prominent lobes and more rounded capsules than have the other ecotypes. Also, flowering is delayed until March and April in these types and their capsules do not mature until late April–May. Coastal populations mature their capsules in February and March.

In NE Nayarit, an extensive population of *G. aridum* was found along the canyon walls of the Rio Cora (22°14′39″ N Lat.–104°30′59″ W Long.) that passes near Jesus Maria. This distribution is unique in that it is in the heart of the Sierra Madre Occidental, although ultimately the water drainage is still towards the Pacific Ocean. All other known populations of *G. aridum* are located on Pacific facing slopes. The Rio Cora Canyon is protected by surrounding mountains and, according to local information, is exceedingly hot most of the year. Although the *G. aridum* in this area was growing at an elevation of 400–500 m, it did not have the hirsute and round capsule characters of the highland ecotypes of Jalisco and Nayarit.

Well-documented germplasm collections of *G. aridum* have now been made from several regions representing different ecotypes. These collections will allow for *ex situ* preservation, maintenance and evaluation. Many of the accessions have been established as growing plants in the *Gossypium* Nursery in Iguala, Guerrero and the remainder will be established. This will allow common-garden comparisons of all populations.

For the most part, *G. aridum* occurs as a part of the native vegetation in deciduous woodlands. It appears to thrive in areas where the woodland is disturbed, particularly along road banks where the canopy is opened. In the niches where it occurs, it is usually found in abundance, although these locations may be separated by many kilometers. This species, as presently circumscribed, is very diverse and does not appear to be threatened.

Gossypium laxum

Prior to the current surveys, the known distribution of *G. laxum* was limited to Cañon Zopilote in central Guerrero. Rio Zopilote is a branch of the Rio Balsas system, and previous collections of this taxon have been near the canyon floor. A new road has been constructed 30 km to the east of Cañon Zopilote that now allows additional access to this region. Although our survey of the area was limited, the new accessions collected of this taxon extend its known range along the floor and the hills above the Rio Balsas for a distance of at least 30 km. The full range of *G. laxum* is yet to be determined, but it probably extends many kilometers along the Rio Balsas watershed east and west of Cañon Zopilote. Like other members of subsection *Erioxylum*, this taxon does well in areas of open sunlight, such as road cuts, although it is also found as part of natural deciduous woodland

vegetation. Morphological diversity is not extensive among the accessions that have been collected thus far.

The *in situ* status of *G. laxum* is not fully known because the extent of its distribution range is unknown. It is common along the base of Cañon Zopilote, and new locations discovered as a result of these surveys indicate that it is not restricted to that niche. Two of our collections were from upland sites above the Rio Balsas canyon. Because the sites where it has been found are generally not suitable for agriculture, this species may be able to survive Mexico's demographic changes and does not seem to be threatened at present.

Gossypium lobatum

Prior to our surveys, the known distribution of *G. lobatum* was restricted to sites within 50 km of Cuatro Caminos, Michoacán. The distribution of these sites suggested to us that the taxon is probably distributed throughout the Rio Tepalcatepec watershed with an eastern extension along the Rio Balsas watershed. Accordingly, the route of our survey was structured on this assumption. A small population of *G. lobatum* trees was encountered 9.2 km W of San Jeronimo, Michoacán at 18 31′32″ N Lat.–101 23′32″ W Long. This is the easternmost extent of its known range. Additional populations were encountered in the hills on the north side of Presa Infiernillo. Our collections in other parts of Michoacán have extended the known distribution of this species southwest to 18°43′31″ N Lat.–102°14′36″ W Long. and to the western edge of the state, near Tepalcatepec at 19°12 ′57 ″ N Lat.–102°48′54″ W Long.

Twelve seed accessions of *G. lobatum* were collected with associated passport data, and nine of these were from previously unrecorded locations. Morphological variation was observed among central populations as well as those at the limits of its distribution, particularly to the west. Unique features of *G. lobatum* are its distichous leaf insertion and tomentose calyces with prominent lobes, the character from which its name is derived. While all accessions had distichous leaves, the calyces of the western populations were less hairy and the lobes less prominent.

As a result of these surveys, we have a better understanding of the *in situ* status of *G. lobatum*. It has a much larger native range than previously recognized, and although much of its range is in agricultural production, it has managed to persist in several areas because of its opportunistic nature of occupying road berms and fence rows where competition for light is reduced. Also, wild areas persist in the eastern part of its range. It is unknown how much suitable habitat has already been destroyed. Overall the species does not appear to be threatened at present.

Gossypium schwendimanii

This is the most recently described *Gossypium* species from Mexico (Fryxell and Koch 1987). We encountered one instance at the Guerrero–Michoacán border near Infiernillo where a population of *G. aridum* was located only 2 km from "typical" *G. schwendimanii*. That *G. aridum* population showed some morphological features that suggested some introgression with *G. schwendimanii*. Information on a herbarium specimen collected in 1990 (DeJoode & Calzada 149, MEXU) suggests that a plant collected from ca. 40 km south of La Huacana, Michoacán near Poturo was a hybrid between *G. schwendimanii* and *G. lobatum*. We collected *G. schwendimanii* from that area and *G. lobatum* about 20 km south of that location. Seed were collected from two additional populations of *G. schwendimanii* from the hills above the west side of Presa Infiernillo. Little morphological diversity was evident among the populations.

The full natural distribution or native range of *G. schwendimanii* is unknown. Because observations during these expeditions determined that *G. schwendimanii* is sympatric with *G. lobatum* north and west of Presa Infernillo, one must speculate that the main distribution of the taxon would to the south and east of this geographical feature in Guerrero. Otherwise, it is difficult to see how it could long exist as a taxon distinct from *G. lobatum* because of their ability to hybridize, and the known range of the latter species as noted previously. Only a field survey can truly answer the question because the area southeast of Presa Infiernillo (western Guerrero) has not been explored for *Gossypium*.

The *in situ* status of *G. schwendimanii* is unclear because of the limited information available on the species. These surveys added little to the pool of

knowledge other than to provide partial documentation on areas where it is not found, and confirmation that it is extant in three locations. Perhaps one factor that will have an impact on its genetic identity is its apparent sympatry with *G. aridum* and *G. lobatum* over parts of its range. We would speculate that these three species are not reproductively isolated, hence introgression in areas of sympatry would be expected, and has been suggested, but not proven, based on intermediate plant types.

Gossypium gossypioides

Even though this survey did not focus on *G. gossypioides*, extensive Mexican territory with a variety of habitats was covered. We only encountered this species in Oaxaca, and the explorations do not provide any new information on its distribution. Based on two accessions that were obtained, herbarium records (MEXU), and the extensive distance along Mexican Hwy 195 in Oaxaca where it was not encountered, we hypothesize that the distribution of *G. gossypioides* may be strongly influenced by elevation, being limited to elevations between approximately 1000 and 1200 m. One aspect of *G. gossypioides* that has not been previously reported is its deciduous habit as a drought escaping mechanism. Fryxell (1979) noted that the capsule of this species abscises at maturity, however, he apparently was unaware of the deciduous nature of the foliage. He noted that the other arborescent species of Mexico defoliated as a mechanism to escape drought. However, he speculated (Fryxell 1979) that the distribution of *G. gossypioides* in a seasonally dry habitat could be attributed to an aggressive root system. We observed that this species, like the other arborescent *Gossypium* species in section *Erioxylum*, occurs in dry deciduous woodlands of Oaxaca and defoliates with the onset of the dry season. However, unlike the species of subsection *Erioxylum*, it flowers and fruits near the end of the wet season before defoliating.

Gossypium sp. nov.

Observations on the distribution of diploid *Gossypium* species in the watersheds that ultimately flow into Presa Infiernillo between Guerrero and Michoacán, namely those of Rio Tepalcatepec and Rio Balsas, indicated the need for further study in those watersheds. An effort was made to reach the eastern tributaries of the Rio Balsas. With the aid of a local resident of a small settlement (Oxtutla) in eastern Guerrero, a *Gossypium* taxon was encountered that initially, in its defoliated condition, resembled *G. aridum*. Subsequent observations on greenhouse plants and a return visit to the site, when the plants had begun to flower with some leaves remaining, indicated that this population represents an undescribed taxon belonging to subsection *Erioxylum*. Its distribution range is unknown, and only one seed accession is available for *ex situ* preservation and evaluation. This taxon has been established in the Mexican *Gossypium* nursery. A formal description of this taxon will be published elsewhere.

Because this species is newly discovered, our current documentation provides the baseline for its *in situ* status. At present, it is known to occur only in a remote area along steep slopes of ravines. But it is likely that human activity will impact in the future it survival as a wild species. In view of the remoteness of the area, it does not appear to be immediately threatened.

Gossypium trilobum

Based on the results of our surveys, special mention should be made of *G. trilobum*. This species belongs to Section *Houzingenia* and is a sister species to *G. thurberi*, the most northerly (Southwestern US) distributed species of *Gossypium*. Distribution of *G. trilobum* is generally limited to moderately high elevations in western Mexico. Fryxell (1979) indicated that it is widely distributed from Sinaloa to Morelos, but few if any collections have been made in the last 20 years. In 2002, and again in 2003, we visited sites where herbarium specimens had been collected in the past. In each of five widely separated locations represented by herbarium collections (sites in N and W México, Jalisco, Michoacán, and Morelos) we were unable to locate plants of the species. In all but one of these locations it appears that agricultural or urban development has destroyed the populations from which the herbarium specimens were collected. Although the status of

G. trilobum in remote areas is unknown, the results of these surveys would indicate that the distribution of this species has been severely eroded by agricultural and human-population pressures on its habitat.

General observations

Botanical relationships and geographical patterns of the ancient commercial routes in the Old World suggest that the first domestic use of cotton took place in southern Arabia (Hutchinson 1959), using the diploid ($2n = 2x = 26$) species of cotton *G. arboreum* and *G. herbaceum*. The main use of cotton in the Old World was to cover wounds and fill linings. In the New World a textile technology of cotton developed independently from that of the Old World based on domestication of the allotetraploid ($2n = 4x = 52$) cotton species, *G. hirsutum* and *G. barbadense*. Archaeological excavation in Coxcatlan, Puebla found specimens of wild cotton bolls dated 5500 years B.C. The Maya civilization (2000 B.C.–1519 A.D.) of Guatemala and Yucatán, Mexico, developed a cotton industry (cotton production and textile industry), later followed by the Aztec civilization (200 B.C.–1519 A.D.) (von Hagen 1961).

Following the domestication of cotton, selection under cultivation in discrete areas of Mexico led to the development of the landraces recognized by the cotton scientists of the last century. Today, only vestiges of the landraces survive as occasional garden plants that are maintained mainly for sentimental reasons. Based on hearsay from local residents, cotton plantings were previously more common throughout southern Mexico. The most frequent explanation given by local peoples for destroying cotton plants that were previously growing in their garden was to make room for fruit trees for food. With worldwide commercial availability of cotton-based products, the need to grow cotton for home use is much less important than the need for food. Without doubt, this trend will continue until even garden plants of cotton are extremely scarce. As these cottons disappear, the accessions that are preserved *ex situ* will be the surviving source of genetic diversity that once resided *in situ* in southern and western Mexico.

Although Mexican scientists have participated in most of the collection expeditions of the last 30 years, no significant germplasm collections remain in the country due to the absence of a viable national cotton germplasm preservation or utilization program. The USSR maintained a scientific presence in Mexico for several years during which a nursery of *G. hirsutum* and some wild *Gossypium* species was maintained. When Russian support was withdrawn, these plantings were abandoned and the area used for other crops. The status of germplasm carried to Russia and China is unknown, although some of the Mexican species are sparsely represented by 1 or 2 plants in the Chinese cotton winter nursery on Hainan Island (JMS, personal observation). All germplasm collected by USA scientists was documented and deposited in the USDA Cotton Germplasm Collection which maintains the accessions for distribution to scientists throughout the world.

The conservation status of wild diploid tree species of *Gossypium* in Mexico presents a different story. These species are part of the indigenous vegetation of the deciduous woodlands of southern and western Mexico. Although they are occasionally found scattered through established woodland, as a group they seem to be opportunistic and quickly establish themselves in newly disturbed soil with open canopy. For this reason, they are encountered most frequently along road banks in hilly woodlands. One could argue that they are seen along roads because that is were the observer is; however, surveys into adjacent established woodlands indicate that the trees are present in much lower numbers away from roads. The degree of threat to some of these species is unknown. This is the first intent to publish a more complete report on the *in situ* status of the cotton germplasm in Mexico. It is difficult to assess and compare how much has been lost without knowing the status of these species 50 or 100 years ago. However, new roads and population growth continue to increase. At this point, one species (*G. aridum*) of the subsection *Erioxylum* appears to be not threatened, probably because of the great diversity (botanical and geographic) encompassed by this species.

The watersheds of central Guerrero and Michoacán are especially important to the *in situ* conservation of *Gossypium* genetic resources in Mexico because all the known species of subsection *Erioxylum* occur there. The Rio Tepalcatepec flows eastward from Colima through Michoacán to Presa Infiernillo, and the Rio Balsas flows

westward from Puebla through Guerrero to the same impoundment. Water from the lake flows south to the Pacific Ocean. In Michoacán, most of the Rio Tepalcatepec watershed supports populations of *G. lobatum*, and, in the area of confluence with Rio Balsas, this species is sympatric with *G. schwendimanii*. Populations of *G. aridum* were found both at the upper reaches of the Rio Balsas in Puebla and below the point of confluence of the two rivers in Guerrero and Michoacán. *Gossypium laxum* occurs along the Rio Balsas in the center of Guerrero. New areas along the Rio Balsas were explored and in a remote area of eastern Guerrero a new taxon was discovered. Exploration to the west along the north side of the river revealed that the area from Arcelia, Guerrero to Huetamo, Michoacán and as far west as San Jeronimo is under extensive agricultural production with few native trees remaining.

In 2002, the Mexican government, in recognition of the unique role of Mexico in the natural history of *Gossypium*, provided a small grant to one of the authors (SG) to establish a permanent nursery for *Gossypium* species in Iguala, Guerrero. All of the diploid species collected in 2002 were established in that nursery, and seeds of the diploid *Gossypium* collected in 1990 from Sonora and Baja California were supplied by the USDA collection to be grown in the nursery. The seeds of the diploid *Gossypium* accessions collected in 2003 are being added to the nursery. It is hoped that Mexico will maintain the *Gossypium* nursery as a working legacy of its natural heritage in cotton.

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